Inverse Trigonometric Functions

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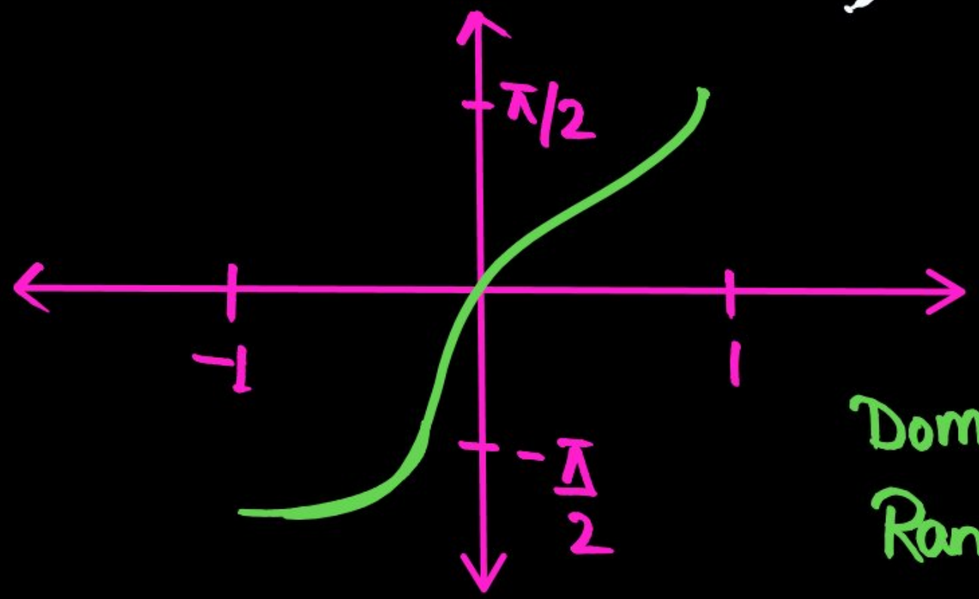
Introduction

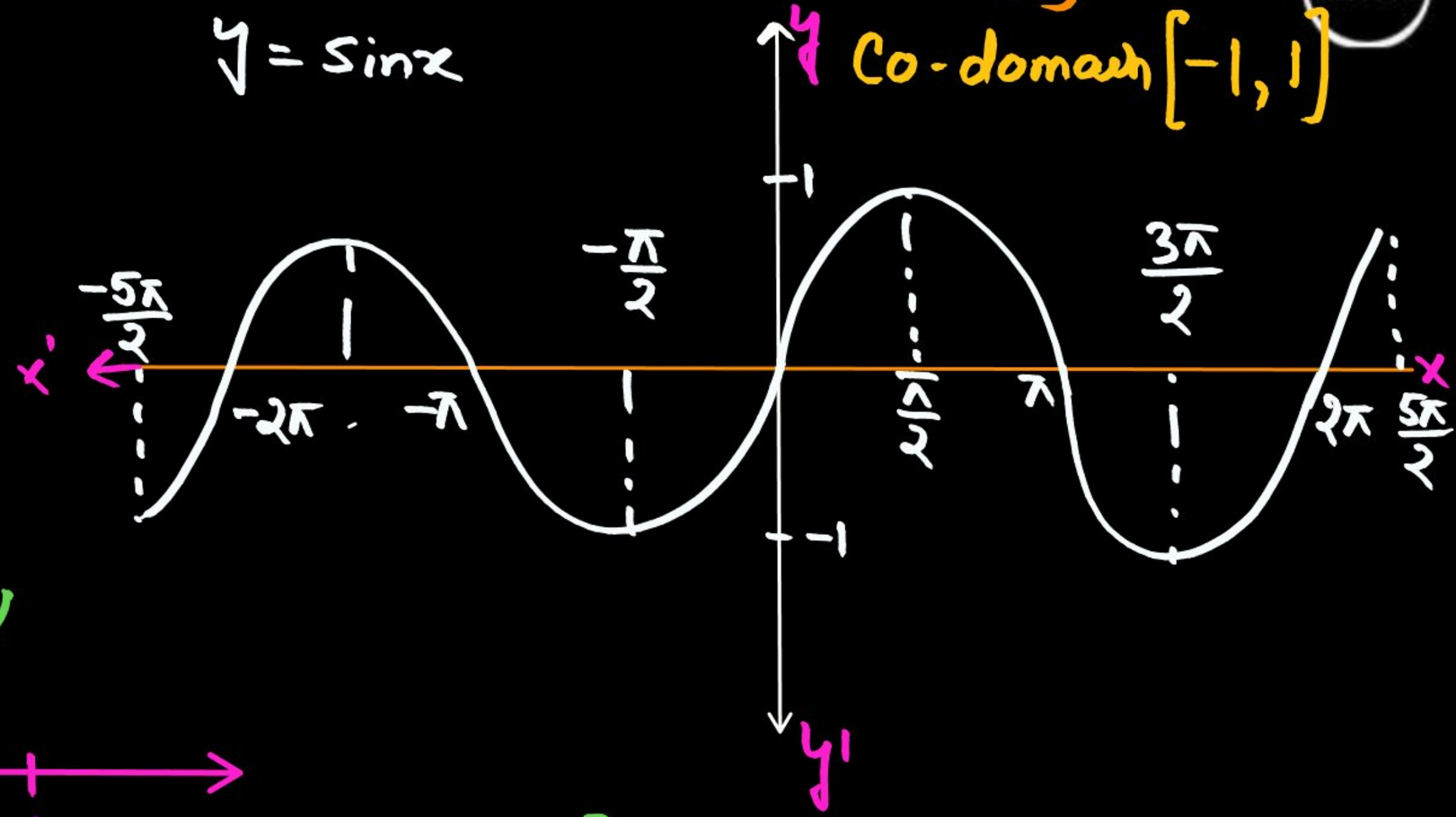
$y = \sin x$

$y = \tan x$

$F(x) = \sin^{-1} x$



Domain → $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$



Domain = $[-1, 1]$

Range = $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$

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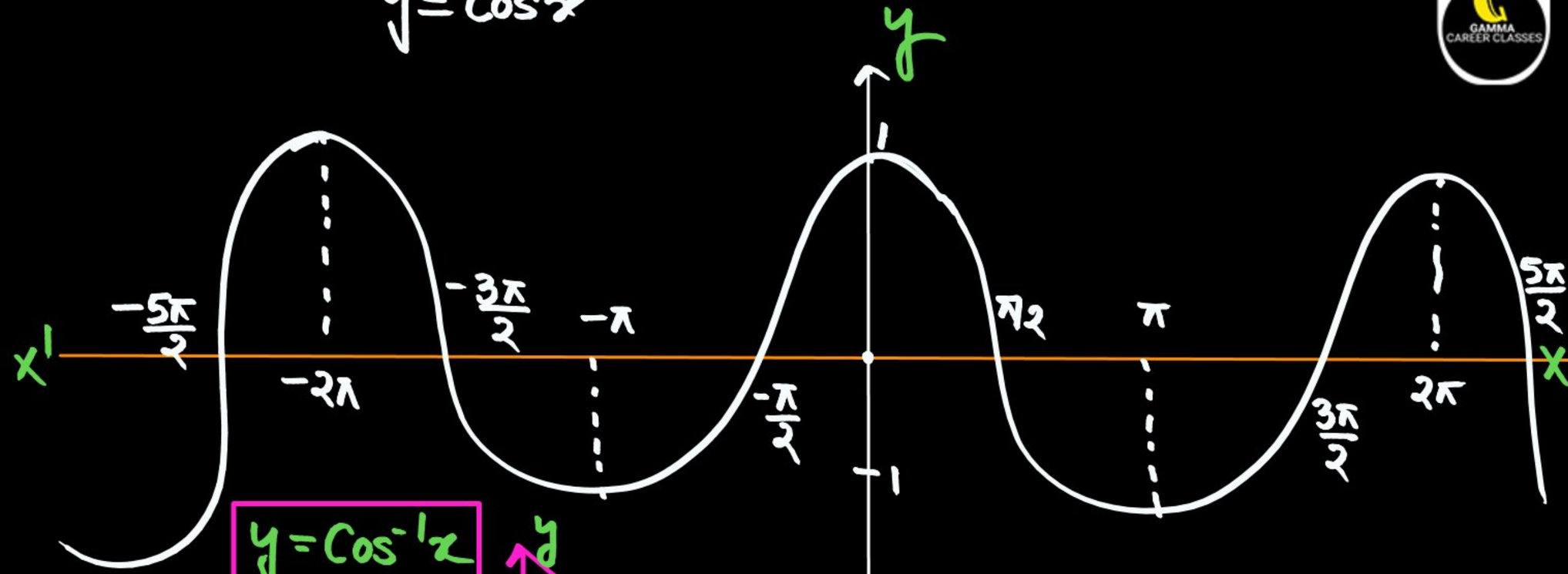
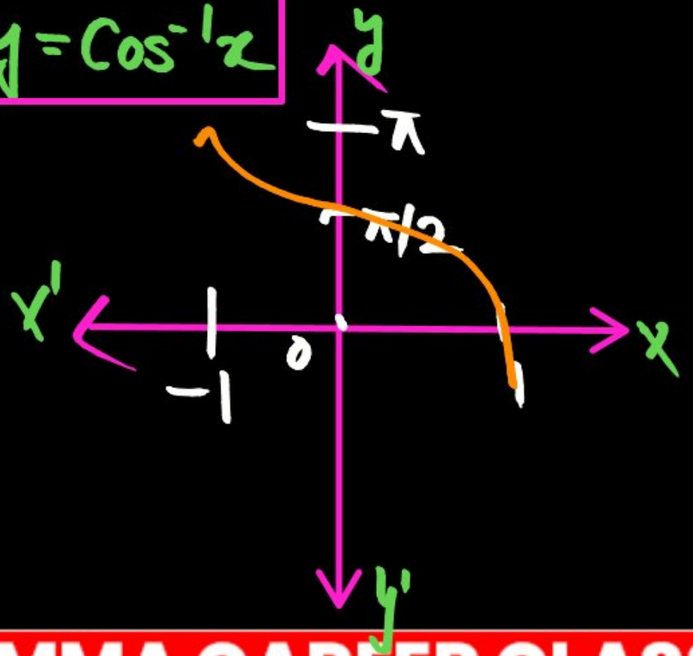
$y = \cos x$



$y = \cos^{-1} x$



$F(x) = \cos^{-1} x$

Domain $= [-1, 1]$

Rang $[0, \pi]$

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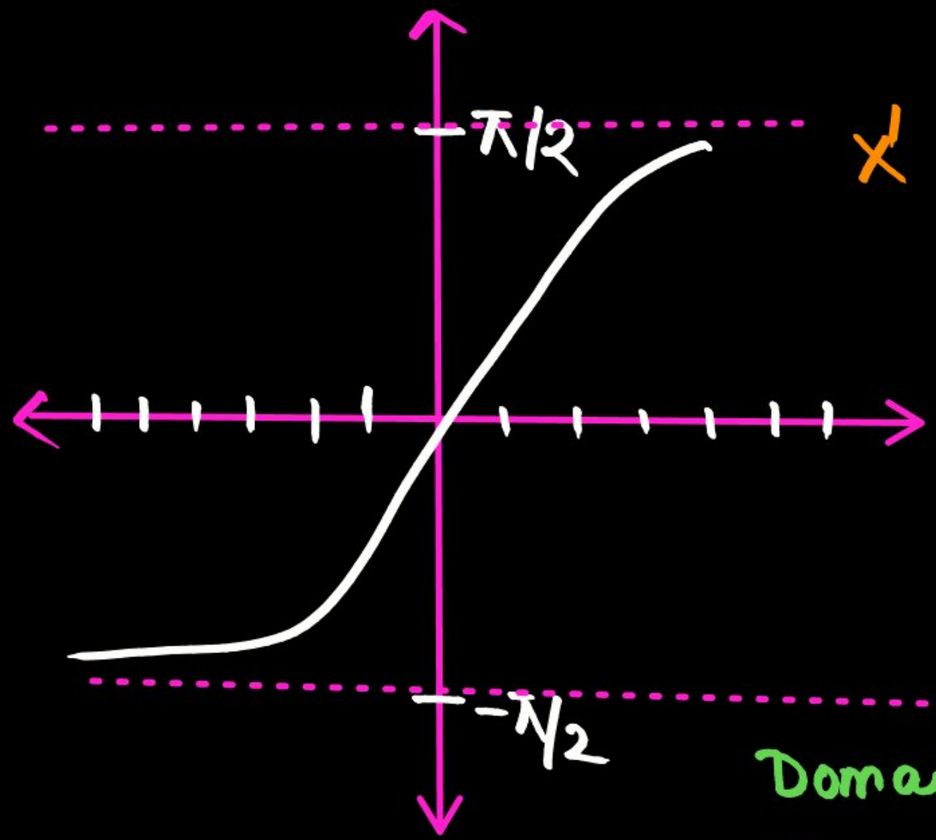
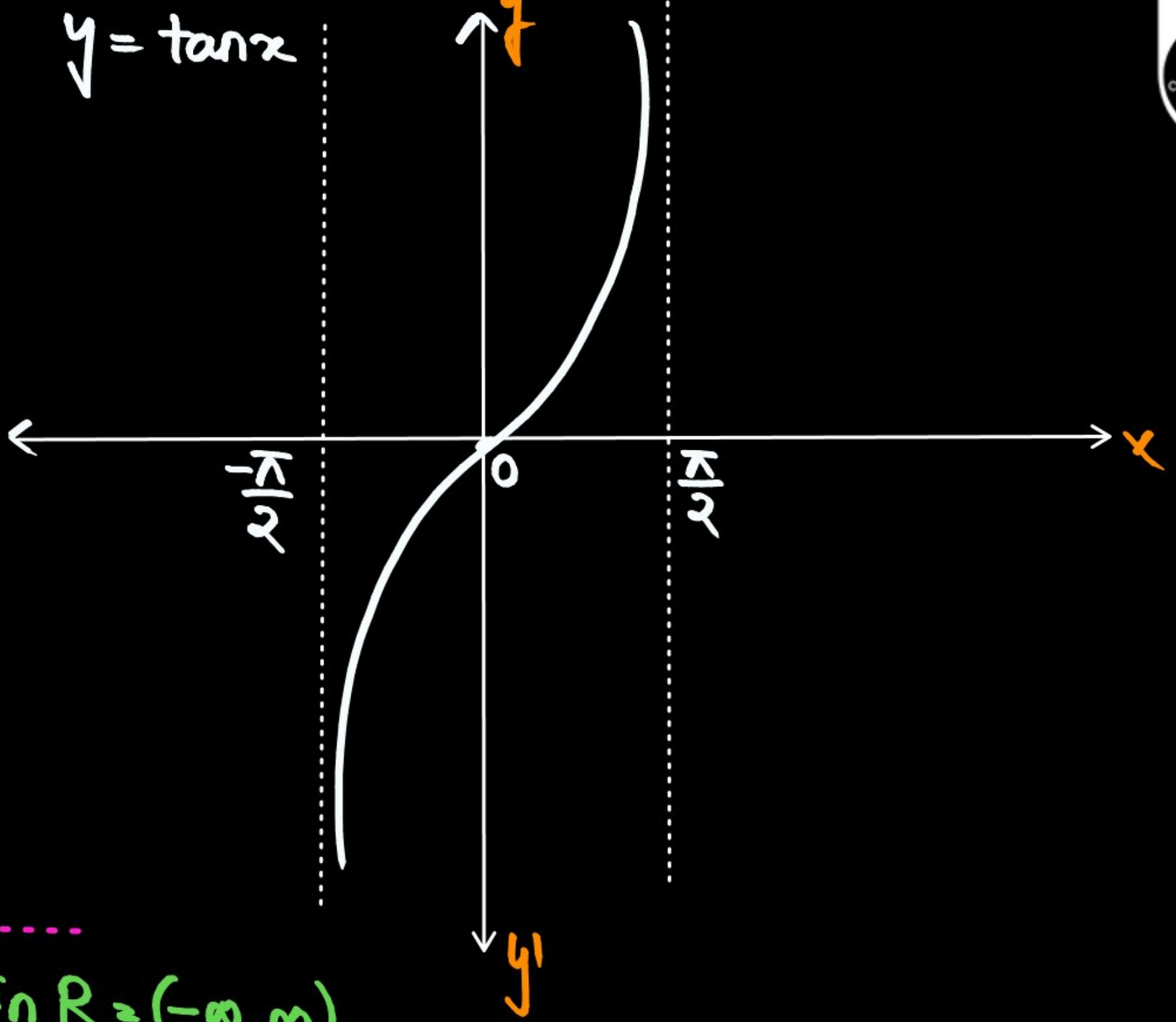
$y = \tan^{-1}x$



$y = \tan x$



Domain $R = (-\infty, \infty)$

Range $= \left(-\frac{\pi}{2}, \pi/2\right)$

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Principle Value Branch

Function	Domain	Range
$y = \sin^{-1} x$	$[-1,1]$	$\left[\frac{-\pi}{2}, \frac{\pi}{2}\right]$
$y = \cos^{-1} x$	$[-1,1]$	$[0, \pi]$
$y = \tan^{-1} x$	$R = (-\infty, \infty)$	$\left(\frac{-\pi}{2}, \frac{\pi}{2}\right)$
$y = \cot^{-1} x$	R	$(0, \pi)$
$y = \sec^{-1} x$	$R - (-1,1)$	$[0, \pi] - \left\{\frac{\pi}{2}\right\}$
$y = \text{cosec}^{-1} x$	$R - (-1,1)$	$\left[\frac{-\pi}{2}, \frac{\pi}{2}\right] - \{0\}$

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Important Result

- $\sin^{-1}(-x) = -\sin^{-1} x\,, when\ x \in [-1,1]$
- $\cos^{-1} x = \pi - \cos^{-1} x\,, when\ x \in [-1,1]$
- $\tan^{-1}(-x) = -\tan^{-1} x, when\ x \epsilon R$
- $\cot^{-1}(-x) = \pi - \cot^{-1} x\,, when\ x \in R$
- $\text{cosec}^{-1}(-x) = -\text{cosec}^{-1} x\,, when\ x \in R - (-1,1)$
- $\sec^{-1}(-x) = \pi - \sec^{-1} x$,when $x \in R - (-1,1)$

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Find the Principal value : $\cos^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Let $y = \cos^{-1}\left(\frac{\sqrt{3}}{2}\right)$

$y = \cos^{-1}\left(\cos\frac{\pi}{6}\right)$

$y = \frac{\pi}{6}$

$0 \le x \le \pi$

$\frac{\pi}{6} \in 0 \le x \le \pi$

Imp →

$\sin^{-1}(\sin x) = x$

$\cos^{-1}(\cos x) = x$

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Find the Principal value: $\sin^{-1}\left(\frac{-\sqrt{3}}{2}\right)$

$$\sin^{-1}(-x) = -\sin^{-1}x$$

Let $y = \sin^{-1}\left(-\frac{\sqrt{3}}{2}\right)$

$$y = -\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

$$= -\sin^{-1}\left[\sin\frac{\pi}{3}\right]$$

$$y = -\frac{\pi}{3} \in \left[-\frac{\pi}{2} \le x \le \frac{\pi}{2}\right]$$

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Find the Principal value: $\cos^{-1}\left(-\frac{1}{\sqrt{2}}\right)$

$\cos^{-1}(-x) = \pi - \cos^{-1}x$

$0 \le x \le \pi$

Let $y = \cos^{-1}\left(\frac{-1}{\sqrt{2}}\right)$

$= \pi - \cos^{-1}\left(\frac{1}{\sqrt{2}}\right)$

$= \pi - \cos^{-1}\left(\cos\frac{\pi}{4}\right)$

$y = \pi - \frac{\pi}{4} = \frac{4\pi - \pi}{4} = \frac{3\pi}{4}$

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Find the Principal value $\sin^{-1}\left(\sin\frac{3\pi}{5}\right)$

Let $y = \sin^{-1}\left(\sin\frac{3\pi}{5}\right)$

$$y = \sin^{-1}\left[\sin\left(\pi - \frac{2\pi}{5}\right)\right]$$

$$= \sin^{-1}\left[\sin\frac{2\pi}{5}\right]$$

$$\boxed{y = \frac{2\pi}{5}}$$

$$\boxed{-\frac{\pi}{2} \le x \le \frac{\pi}{2}}$$

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Using Principal values find the values of :

$\tan^{-1}\sqrt{3} - \sec^{-1}(-2)$

$\sec^{-1}(-x) = \pi - \sec^{-1}x$

Let $y = \tan^{-1}\sqrt{3} - \sec^{-1}(-2)$

$y = \tan^{-1}\left(\tan\frac{\pi}{3}\right) - \left[\pi - \sec^{-1}2\right]$

$= \frac{\pi}{3} - \pi + \sec^{-1}2$

$= \frac{\pi}{3} - \pi + \sec^{-1}\left(\sec\frac{\pi}{3}\right)$

$y = \frac{\pi}{3} - \pi + \frac{\pi}{3} = \frac{\pi - 3\pi + \pi}{3} = -\frac{\pi}{3}$

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Using Principal values find the values of :

$$\tan^{-1}(1) + \cos^{-1}\left(\frac{-1}{2}\right) + \sin^{-1}\left(-\frac{1}{2}\right)$$

$\therefore$ $\cos^{-1}(-x) = \pi - \cos^{-1}x$

$\sin^{-1}(-x) = -\sin^{-1}x$

$$y = \tan^{-1}(1) + \cos^{-1}\left(-\tfrac{1}{2}\right) + \sin^{-1}\left(-\tfrac{1}{2}\right)$$

$$= \tan^{-1}\left(\tan\tfrac{\pi}{4}\right) + \pi - \cos^{-1}\left(\tfrac{1}{2}\right) - \sin^{-1}\left(\tfrac{1}{2}\right)$$

$$= \frac{\pi}{4} + \pi - \cos^{-1}\left(\cos\tfrac{\pi}{3}\right) - \sin^{-1}\left(\sin\tfrac{\pi}{6}\right)$$

$$= \frac{\pi}{4} + \pi - \frac{\pi}{3} - \frac{\pi}{6}$$

$$y = \frac{3\pi + 12\pi - 4\pi - 2\pi}{12} = \frac{9\pi}{12} = \frac{3\pi}{4}$$

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Evaluate: $\sin\left(\frac{\pi}{3} - \sin^{-1}\left(\frac{-1}{2}\right)\right)$

$$y = \sin\left(\frac{\pi}{3} - \sin^{-1}\left(-\frac{1}{2}\right)\right)$$

$$y = \sin\left[\frac{\pi}{3} + \sin^{-1}\left(\frac{1}{2}\right)\right]$$

$$= \sin\left[\frac{\pi}{3} + \sin^{-1}\left(\sin\frac{\pi}{6}\right)\right]$$

$$= \sin\left[\frac{\pi}{3} + \frac{\pi}{6}\right] = \sin\left[\frac{2\pi+\pi}{6}\right] = \sin\left[\frac{3\pi}{6}\right] = \sin\left[\frac{\pi}{2}\right] = 1$$

$$\boxed{y = 1}$$

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Evaluate: $\sin\left(2\sin^{-1}\frac{2}{3}\right)$

$$y = \sin\left[2\sin^{-1}\frac{2}{3}\right]$$

but

$$\sin^{-1}\frac{2}{3} = \theta$$

$$\boxed{\sin\theta = \frac{2}{3}}$$

$$\cos\theta = \sqrt{1-\sin^2\theta}$$

$$= \sqrt{1-\left(\frac{2}{3}\right)^2} = \sqrt{1-\frac{4}{9}} = \frac{\sqrt{5}}{3}$$

$$y = \sin 2\theta$$

$$= 2\sin\theta\cos\theta$$

$$= 2 \times \frac{2}{3} \times \frac{\sqrt{5}}{3} = \frac{4\sqrt{5}}{9}$$

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Evaluate: $\tan\left(\frac{1}{2}\sin^{-1}\frac{3}{5}\right)$

$$y = \tan\left(\frac{1}{2}\sin^{-1}\frac{3}{5}\right)$$

but $\frac{1}{2}\sin^{-1}\frac{3}{5} = \theta$

$$\sin^{-1}\frac{3}{5} = 2\theta$$

$$\sin 2\theta = \frac{3}{5}$$

$$\frac{2\tan\theta}{1+\tan^2\theta} = \frac{3}{5}$$

$$\sin 2\theta = \frac{2\tan\theta}{1+\tan^2\theta}$$

$$\left(\tan 2\theta = \frac{2\tan\theta}{1-\tan^2\theta}\right)$$

$$10\tan\theta = 3 + 3\tan^2\theta$$

$$3\tan^2\theta - 10\tan\theta + 3 = 0$$

$$3\tan^2\theta - (9+1)\tan\theta + 3 = 0$$

$$3\tan^2\theta - 9\tan\theta - \tan\theta + 3 = 0$$

$$3\tan\theta(\tan\theta - 3) - 1(\tan\theta - 3) = 0$$

$$(\tan\theta - 3)(3\tan\theta - 1) = 0$$

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$$(\tan\theta - 3)(3\tan\theta - 1) = 0$$

$\tan\theta = 3$ ✗

$$3\tan\theta - 1 = 0$$

$$\tan\theta = \frac{1}{3}$$

$$-\frac{\pi}{4} \leq x \leq \frac{\pi}{4}$$

$$\tan\theta = \frac{1}{3}$$

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Formula

- $\sin^{-1} x + \cos^{-1} x = \frac{\pi}{2}, x \in [-1,1]$
- $\tan^{-1} x + \cot^{-1} x = \frac{\pi}{2}, x \in R$
- $\sec^{-1} x + \operatorname{cosec}^{-1} x = \frac{\pi}{2}, x \in R - [-1,1]$
- $\tan^{-1} x + \tan^{-1} y = \tan^{-1}\left(\frac{x+y}{1-xy}\right), if\ xy < 1$
- $\tan^{-1} x - \tan^{-1} y = \tan^{-1}\left(\frac{x-y}{1+xy}\right), if\ xy > 1$
- $2\tan^{-1} x = \sin^{-1}\frac{2x}{1+x^2}, -1 \le x \le 1$
- $2\tan^{-1} x = \cos^{-1}\frac{1-x^2}{1+x^2} : x \ge 0$
- $2\tan^{-1} x = \tan^{-1}\frac{2x}{1-x^2}$ -1<x<1

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Formulae

(i) $\sin(x+y) = \sin x \cos y + \cos x \sin y$

(ii) $\sin(x-y) = \sin x \cos y - \cos x \sin y$

(iii) $\cos(x+y) = \cos x \cos y - \sin x \sin y$

(iv) $\cos(x-y) = \cos x \cos y + \sin x \sin y$

(v) $\tan(x+y) = \frac{\tan x + \tan y}{1 - \tan x \cdot \tan y}$

(vi) $\tan(x-y) = \frac{\tan x - \tan y}{1 + \tan x \cdot \tan y}$

(vii) $\cot(x+y) = \frac{\cot x \cdot \cot y - 1}{\cot y + \cot x}$

(viii) $\cot(x-y) = \frac{\cot x \cdot \cot y + 1}{\cot y - \cot x}$

(ix) $\sin 2x = 2 \sin x \cos x = \frac{2 \tan x}{1 + \tan^2 x}$

(ix) $\sin 2x = 2 \sin x \cos x = \frac{2 \tan x}{1 + \tan^2 x}$

(x) $\cos 2x = \cos^2 x - \sin^2 x = 2\cos^2 x -$

$1 = 1 - 2\sin^2 x = \frac{1 - \tan^2 x}{1 + \tan^2 x}$

(xii) $\sin 3x = 3 \sin x - 4 \sin^3 x$

(xiii) $\cos 3x = 4 \cos^3 x - 3 \cos x$

(xiv) $\tan 3x = \frac{3 \tan x - \tan^3 x}{1 - 3 \tan^2 x}$

(xv) $\cos x + \cos y = 2 \cos \frac{x+y}{2} \cos \frac{x-y}{2}$

(xvi) $\cos x - \cos y = 2 \sin \frac{x+y}{2} \sin \frac{y-x}{2}$

(xvii) $\sin x + \sin y = 2 \sin \frac{x+y}{2} \cos \frac{x-y}{2}$

(xviii) $\sin x - \sin y = 2 \cos \frac{x+y}{2} \sin \frac{x-y}{2}$

(xix) $2 \sin x \cos y = \sin(x+y) + \sin(x-y)$

(xx) $2 \cos x \sin y = \sin(x+y) - \sin(x-y)$

(xxi) $2 \cos x \cos y = \cos(x+y) + \cos(x-y)$

(xxii) $2 \sin x \sin y = \cos(x-y) - \cos(x+y)$

(xxiii) $\sin \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{2}}$

(xxiv) $\cos \frac{A}{2} = \pm \sqrt{\frac{1 + \cos A}{2}}$

(xxv) $\tan \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{1 + \cos A}}$

sign ' + ' or '–' will be decided according to the quadrant in which angle lies.

- Cos (-x) = cos x
- Sec (-x) = sec x
- Sin (-x) = sin x
- Cosec (-x) = - cosec x
- Tan (-x) = - tan x
- Cot (-x) = - cot x

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Find the value of : $\tan^{-1}\left(\frac{x}{y}\right) - \tan^{-1}\left(\frac{x-y}{x+y}\right)$

but

$$z = \tan^{-1}\left(\frac{x}{y}\right) - \tan^{-1}\left(\frac{x-y}{x+y}\right)$$

$$z = \tan^{-1}\left(\frac{x}{y}\right) - \tan^{-1}\left(\frac{\frac{x}{y}-1}{\frac{x}{y}+1}\right)$$

$$z = \tan^{-1}\frac{x}{y} - \left[\tan^{-1}\left(\frac{x}{y}\right) - \tan^{-1}(1)\right]$$

$$= \tan^{-1}\frac{x}{y} - \left[\tan^{-1}\frac{x}{y} - \tan^{-1}\left(\tan\frac{\pi}{4}\right)\right]$$

$$z = \tan^{-1}\frac{x}{y} - \tan^{-1}\frac{x}{y} + \tan^{-1}\left(\tan\frac{\pi}{4}\right) = \pi/4$$

$\because$ $\tan^{-1}x + \tan^{-1}y = \tan^{-1}\left(\frac{x-y}{1+xy}\right)$

$$\tan(x-y) = \frac{\tan x - \tan y}{1+\tan x \tan y}$$

$$\boxed{z = \frac{\pi}{4}}$$

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Write the following functions in the simplest form

$$\tan^{-1}\left(\frac{\cos x}{1+\sin x}\right)$$

$$y = \tan^{-1}\left(\frac{\cos x}{1+\sin x}\right)$$

$$= \tan^{-1}\left[\frac{\sin\left(\frac{\pi}{2}-x\right)}{1+\cos\left(\frac{\pi}{2}-x\right)}\right]$$

$$= \tan^{-1}\left[\frac{2\sin\left(\frac{\pi}{4}-\frac{x}{2}\right)\cos\left(\frac{\pi}{4}-\frac{x}{2}\right)}{1+2\cos^2\left(\frac{\pi}{4}-\frac{x}{2}\right)-1}\right]$$

$$\sin x = 2\sin\frac{x}{2}\cos\frac{x}{2}$$

$$\cos x = 2\cos^2\frac{x}{2} - 1$$

$$\cos x = 1 - 2\sin^2\frac{x}{2}$$

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$$y = \tan^{-1}\left[\frac{2\sin\left(\frac{\pi}{4}-\frac{x}{2}\right)\cos\left(\frac{\pi}{4}-\frac{x}{2}\right)}{2\cos^2\left(\frac{\pi}{4}-\frac{x}{2}\right)}\right]$$

$$= \tan^{-1}\left[\frac{\sin\left(\frac{\pi}{4}-\frac{x}{2}\right)}{\cos\left(\frac{\pi}{4}-\frac{x}{2}\right)}\right]$$

$$y = \tan^{-1}\left[\tan\left(\frac{\pi}{4}-\frac{x}{2}\right)\right] = \boxed{\frac{\pi}{4}-\frac{x}{2}} \quad \text{Ans}$$

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Simplify : $\cos^{-1}\left(\frac{3}{5}\cos x + \frac{4}{5}\sin x\right)$

Let $Z = \cos^{-1}\left(\frac{3}{5}\cos x + \frac{4}{5}\sin x\right)$

Let $\frac{3}{5} = \cos\alpha \Rightarrow \alpha = \cos^{-1}\frac{3}{5}$

$$\sin\alpha = \sqrt{1-\cos^2\alpha} = \sqrt{1-\left(\frac{3}{5}\right)^2} = \sqrt{\frac{25-9}{25}} = \sqrt{\frac{16}{25}} = \frac{4}{5}$$

$$Z = \cos^{-1}\left[\cos\alpha\cos x + \sin\alpha\sin x\right]$$

$$= \cos^{-1}\left[\cos(\alpha - x)\right]$$

$$\boxed{Z = \alpha - x = \cos^{-1}\frac{3}{5} - x}$$ Ans

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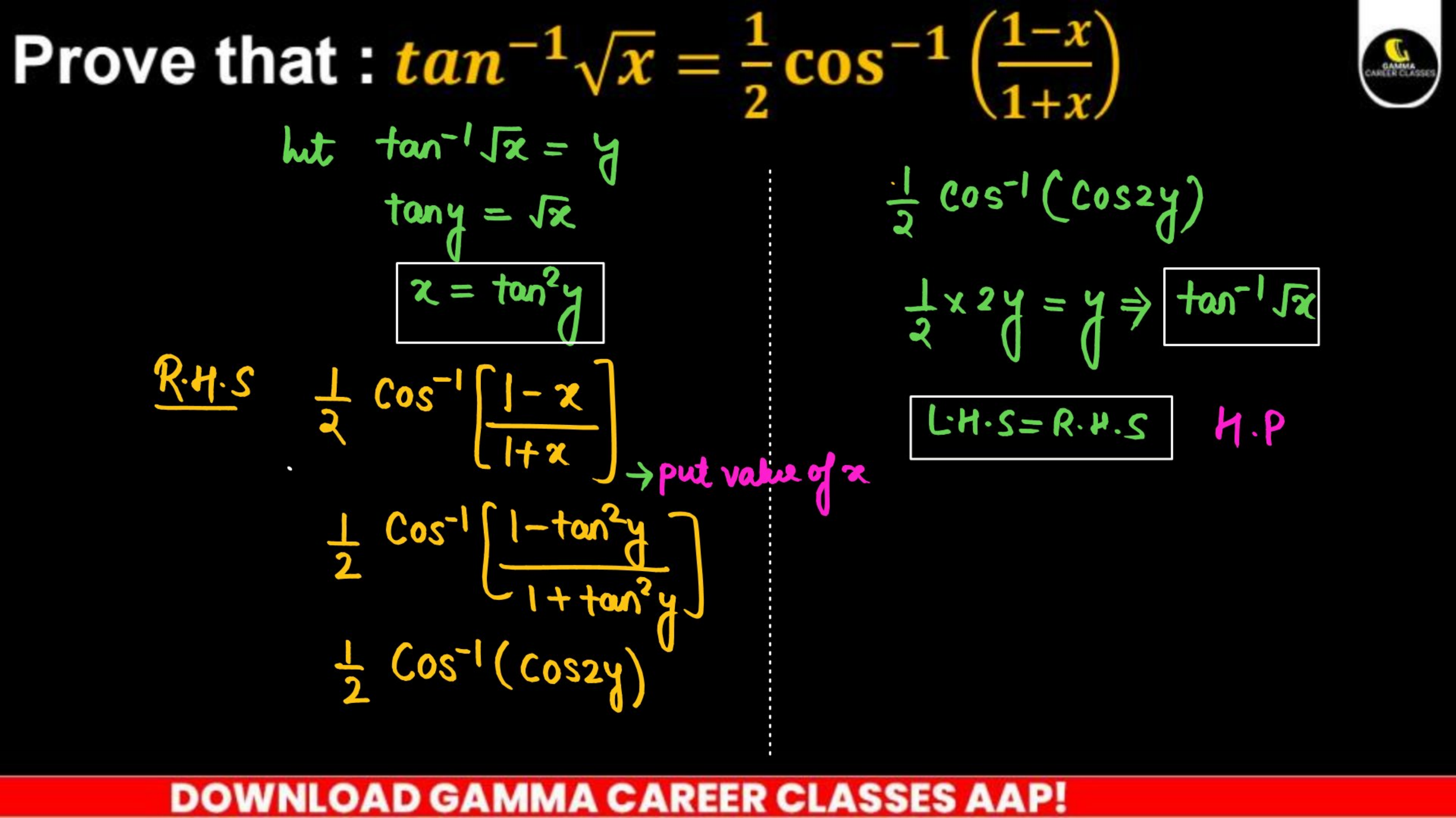
Prove that : $tan^{-1}\sqrt{x} = \frac{1}{2}\cos^{-1}\left(\frac{1-x}{1+x}\right)$



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Prove that : $\cos(\tan^{-1}(\sin(\cot^{-1}x))) = \sqrt{\frac{1+x^2}{2+x^2}}$

L.H.S $\cos(\tan^{-1}(\sin(\cot^{-1}x)))$

Let $\cot^{-1}x = y \Rightarrow \boxed{x = \cot y}$

$\boxed{\text{Cosec}\, y = \sqrt{1+\cot^2 y}}$

$\text{Cosec}\, y = \sqrt{1+x^2}$

$\sin y = \frac{1}{\sqrt{1+x^2}}$

Let $\boxed{\tan^{-1}\left(\frac{1}{\sqrt{1+x^2}}\right) = z}$

$\tan z = \frac{1}{\sqrt{1+x^2}}$

$\sec z = \sqrt{1+\tan^2 z} = \sqrt{1+\frac{1}{(1+x^2)}}$

$\sec z = \sqrt{\frac{1+x^2+1}{1+x^2}}$

$\sec z = \sqrt{\frac{2+x^2}{1+x^2}}$

$\cos z = \sqrt{\frac{1+x^2}{2+x^2}} \Rightarrow z = \cos^{-1}\left(\frac{\sqrt{1+x^2}}{\sqrt{2+x^2}}\right)$

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$$\cos\left(\cos^{-1}\frac{\sqrt{1+x^2}}{\sqrt{2+x^2}}\right) = \sqrt{\frac{1+x^2}{2+x^2}}$$

$$L.H.S = R.H.S$$

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If $\sec^{-1} x = \operatorname{cosec}^{-1} y$, show that $\frac{1}{x^2} + \frac{1}{y^2} = 1$

$\sec^{-1} x = \operatorname{cosec}^{-1} y = t$

$\sec^{-1} x = t$ | $\operatorname{cosec}^{-1} y = t$

$\sec t = x$ | $\operatorname{cosec} t = y$

$\cos t = \frac{1}{x}$ — (1) | $\sin t = \frac{1}{y}$ — (2)

$(1)^2 + (2)^2$

$\cos^2 t + \sin^2 t = \frac{1}{x^2} + \frac{1}{y^2}$

$1 = \frac{1}{x^2} + \frac{1}{y^2}$

$\frac{1}{x^2} + \frac{1}{y^2} = 1$ Ans

H.P

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Find the value of x :

$$3\sin^{-1}\left(\frac{2x}{1+x^2}\right)-4\cos^{-1}\left(\frac{1-x^2}{1+x^2}\right)+2\tan^{-1}\left(\frac{2x}{1-x^2}\right)=\frac{\pi}{3}$$

Let $x=\tan\theta \Rightarrow \boxed{\theta=\tan^{-1}x}$

$$3\sin^{-1}\left[\frac{2\tan\theta}{1+\tan^2\theta}\right]-4\cos^{-1}\left[\frac{1-\tan^2\theta}{1+\tan^2\theta}\right]+2\tan^{-1}\left[\frac{2\tan\theta}{1-\tan^2\theta}\right]=\frac{\pi}{3}$$

$$3\sin^{-1}[\sin 2\theta]-4\cos^{-1}[\cos 2\theta]+2\tan^{-1}[\tan 2\theta]=\frac{\pi}{3}$$

$$3\times 2\theta-4\times 2\theta+2\times 2\theta=\frac{\pi}{3}$$

$$6\times\tan^{-1}x-8\tan^{-1}x+4\tan^{-1}x=\frac{\pi}{3}$$

$$2\tan^{-1}x=\frac{\pi}{3}$$

$$\tan^{-1}x=\frac{\pi}{6}$$

$$x=\tan\pi/6=\frac{1}{\sqrt{3}}$$ Ans

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Prove that :- $\tan^{-1}\frac{2}{11}+\tan^{-1}\frac{7}{24}=\tan^{-1}\frac{1}{2}$

L.H.S

$\tan^{-1}\frac{2}{11}+\tan^{-1}\frac{7}{14}$

$\tan^{-1}\left[\frac{\frac{2}{11}+\frac{7}{14}}{1-\frac{2}{11}\times\frac{7}{14}}\right]$

R.H.S

$$\tan^{-1}x+\tan^{-1}y=\tan^{-1}\left(\frac{x+y}{1-xy}\right)$$

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If $\tan^{-1}x + \tan^{-1}y + \tan^{-1}z = \pi$ then Prove that : $x + y + z = xyz$

(Imp $-\infty$)

$$\tan^{-1}x + \tan^{-1}y + \tan^{-1}z = \pi$$

$$\tan^{-1}x + \tan^{-1}y = \pi - \tan^{-1}z$$

$$\tan^{-1}\left[\frac{x+y}{1-xy}\right] = \pi - \tan^{-1}z$$

$$\frac{x+y}{1-xy} = \tan\left[\pi - \tan^{-1}z\right]$$

$\tan(\pi-\theta)$
$-\tan\theta$
$-\tan(\tan^{-1}z)$
$= -z$ Ans

$$\frac{x+y}{1-xy} = -z$$

$$x+y = -z(1-xy)$$

$$x+y = -z+xyz$$

$$\boxed{x+y+z = xyz}$$

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If $\tan^{-1}x + \tan^{-1}y + \tan^{-1}z = \frac{\pi}{2}$ $x, y, z. > 0$ then find the value of $xy + yz + zx$

$$\tan^{-1}x + \tan^{-1}y + \tan^{-1}z = \frac{\pi}{2}$$

$$\tan^{-1}x + \tan^{-1}y = \frac{\pi}{2} - \tan^{-1}z$$

$$\tan^{-1}\left[\frac{x+y}{1-xy}\right] = \frac{\pi}{2} - \tan^{-1}z$$

$$\frac{x+y}{1-xy} = \tan\left[\frac{\pi}{2} - \tan^{-1}z\right]$$

$$\frac{x+y}{1-xy} = \cot\left(\tan^{-1}z\right)$$

$$\frac{x+y}{1-xy} = \cot\left(\cot^{-1}\frac{1}{z}\right)$$

$$\frac{x+y}{1-xy} = \frac{1}{z}$$

$$zx + yz = 1 - xy$$

$$xy + yz + zx = 1$$ Ans

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Thank you!

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